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A METHOD OF ESTIMATING THE SIGNAL-TO-NOISE RATIO IN A
TELECOMMUNICATIONS RECEIVER AND AN APPLICATION OF THE
METHOD TO CONTROLLING A TRANSMITTER

a

Background of the invention

The invention relates to a method of estimating the
5 signal-to-noise ratio of a signal received by a
radiocommunications receiver. It also relates to a
receiver for implementing the method and to an
application of the method to controlling the power of a
transmitter.

10 A telecommunications system generally transmits a
large number of different calls simultaneously.

By way of example, the telecommunications system
considered herein is one in which terminals communicate
with a control or connection station, in particular via
15 retransmission means on a satellite. Calls between
terminals are effected via the control station. The
control station therefore communicates simultaneously
with a set of terminals.

In the above telecommunications system, the number
20 of calls that can be transmitted simultaneously depends
on the retransmission power available on the satellite.
To maximize the capacity of the system, in other words to
maximize the number of calls that can be transmitted
simultaneously, it is necessary to minimize the power
25 allocated to each transmitter, because the retransmission
power is necessarily limited. However, this constraint
is difficult to reconcile with the requirement to
optimize call quality, which requires sufficient
transmission power. As a general rule, the calls are
30 digital calls and transmission quality is assessed
against a maximum permitted error rate. The permitted
error rate is guaranteed if the received signal-to-noise
ratio is above a pre-determined threshold.

Thus the power of a transmitter is generally
35 determined from the signal-to-noise ratio measured at the
associated receiver and the signal-to-noise ratio is
generally measured continuously, in particular in a

satellite transmission system, because propagation conditions can vary, in particular because of variations in meteorological conditions. For example, rain causes strong attenuation of the received signal compared to transmission in fine weather. Propagation conditions can also be degraded by scintillation due to multiple signal paths causing additive and subtractive combination of signals. Propagation conditions can also be degraded because of masking when an antenna is tracking a mobile source (here the satellite) and obstacles block the path of the transmitted signal.

The measured signal-to-noise ratio of a received signal is itself generally subject to estimation noise and the measurements are usually smoothed, for example by low-pass filtering, to reduce the estimation noise.

The accuracy of the measured signal-to-noise ratio determines the capacity of the telecommunications system. If the measurement is accurate, each transmitter is allocated just the necessary power, which therefore maximizes the communications resources, whereas an inaccurate measurement leads to the allocation of too much power to each transmitter, which is not favorable to maximizing communications capacity.

Summary of the invention
The invention improves the accuracy of the estimated signal-to-noise ratio and thus supplies a set point signal to the associated transmitter which minimizes the power it transmits.

To this end, the invention estimates the signal and the noise separately and the signal and the noise are filtered separately before dividing signal by noise. It has been found that filtering each component separately prior to division reduces the estimation noise.

In one embodiment, the signal and the noise are filtered differently, preferably in ways that are respectively suited to the signal and to the noise. The signal and the noise are variables of different kinds, in particular because of their different physical origins,

and so a form of processing suited to one of the variables is not necessarily suited to the other one, for example, because their amplitudes and frequency bands are usually very different.

5 Also, when the traffic is sporadic, the power of the signal can be estimated only when data signals are present, although noise can be measured continuously.

10 A low-pass filter is preferably used to filter the wanted signal prior to division, on the one hand to achieve a significant reduction in the signal estimation noise and on the other hand to achieve a sufficiently short control loop response time. To this end, either a finite impulse response filter is used, for example an averaging filter, or an infinite impulse response filter
15 is used, for example a first order filter. A first order infinite impulse response filter is preferable in the case of sporadic traffic because it gives more weight to more recent data than to less recent data.

20 Statistical smoothing that allows for the random nature of the noise is preferably used to filter or smooth the noise estimate. To this end, the statistical distribution of the noise power measurements is observed over a particular period chosen to be long enough to collect a large (statistically representative) number of
25 measurements but such that the noise retains a static behavior during that period. A noise level above the average value is then chosen to constitute a limit value beyond which the probability of the estimated noise power exceeding that limit during the observation period is
30 below a low threshold ϵ .

In other words, to estimate the noise, instead of calculating an average value, a histogram of noise levels is considered and the spread of the noise levels is determined.

35 In the simplest case, the highest noise level over a suitably long observation period is chosen, for example a period of the order of one second.

The noise level can also be estimated as a function of known parameters of the noise. For example, if it is known that the noise is Gaussian noise, the average μ and the variance σ^2 of the distribution are calculated and the smoothed value is $\mu + n\sigma$, where σ is a standard deviation and n is an integer such that the probability of the noise power not exceeding the value $\mu + n\sigma$ is less than the low threshold ε .

More generally, the average and the variance, i.e. the moments of the distribution, are used to estimate the noise power.

Statistical smoothing of the estimate is particularly beneficial in the event of jamming.

It is also possible to use a low-pass finite or infinite impulse response noise filter, for example in the presence of thermal noise.

The present invention applies primarily to estimating the signal-to-noise ratio of a wanted signal, i.e. of a data signal.

The present invention provides a method of estimating the signal-to-noise ratio of a wanted signal, in particular a digital signal, received by a radiocommunications receiver. The method is characterized in that, to minimize the estimation noise of the signal-to-noise ratio, the signal and the noise are estimated separately and the signal and the noise are filtered separately before division of the signal by the noise.

In an embodiment the filtering of the wanted signal is different from the filtering of the noise signal.

In an embodiment, to filter the noise signal, the statistical distribution of the noise power measurements is observed for a particular period during which a statistically representative number of measurement samples is collected and which is sufficiently short for the noise to remain practically stationary.

In another embodiment the noise level used has a

value such that the probability that the noise level exceeds that value is less than a predetermined threshold during the observation period.

5 In an embodiment the noise value used is the maximum value over the particular period.

In an embodiment the moments of the distribution are determined.

10 In an embodiment the average and the variance of the distribution are determined and the noise value used is $\mu + n\sigma$, where σ is a standard deviation and n is a number determined according to the predetermined threshold.

In an embodiment a finite or infinite impulse response low-pass filter is used to filter the noise signal.

15 In an embodiment a finite impulse response filter is used to filter the wanted signal.

In an embodiment the finite impulse response filter is an averaging filter.

20 In an embodiment the transmitter delivers a reference signal with a regular period at a particular level and the signal-to-noise ratio is estimated from that reference signal.

In an embodiment an infinite impulse response filter is used to filter the estimate of the wanted signal.

25 In an embodiment a first order auto-regressive filter is used, for example, as expressed by the equation:

$$\hat{x}_i = (1-a)\tilde{x}_i + a\hat{x}_{i-1}$$

30 where \tilde{x}_i represents the instantaneous estimate of the wanted signal at time i , \hat{x}_i represents the smoothed estimate of the wanted signal at time i and a is an integration coefficient.

35 In an embodiment packets or cells are received sporadically and each packet or cell received is filtered.

The invention also provides an application of the

method according to the invention to estimating the signal-to-noise ratio in a telecommunications receiver sending data for controlling the power of a corresponding transmitter. *Brief description of the drawings*

5 Other features and advantages of the invention will become apparent on reading the following description of embodiments of the invention, which description is given with reference to the accompanying drawings, in which:

Figure 1 is a diagram of a transmitter and a
10 receiver using the method according to the invention,

Figure 2 is a diagram of a telecommunications system to which the method according to the invention is applied, and

Figure 3 is a diagram explaining some aspects of the
15 filtering used in the receiver shown in Figure 1.

Detailed description of the invention
Figure 1 shows a transmitter 10 and a receiver 12. The power P_e of the transmitter 10 is determined by a set point signal δP_e supplied by the receiver 12.

In the example, the transmitter and the receiver are
20 parts of a telecommunications system in which calls are transmitted via non-geostationary satellites 14 (Figure 2) in low or medium Earth orbit, at an altitude of the order of 1 450 km in the example. The Earth is divided into areas 16 each of which is 700 km in diameter, for
25 example, and each area 16 includes a control or connection station 18, which is centrally located therein, for example, and a plurality of terminals 20_1 , 20_2 , etc. The connection station 18 is connected to one or more other networks 22, for example terrestrial
30 networks.

A call between two terminals 20_1 and 20_2 is effected via the satellite 14 and the station 18. To be more precise, when the terminal 20_1 is communicating with the terminal 20_2 , the signal transmitted by the terminal 20_1
35 is transmitted to the station 18 via the satellite 14 and the station 18 forwards the signal to the terminal 20_2 , also via the satellite 14. By "satellite" is meant the

retransmission means on board the satellite, of course.

Likewise, a call between a terminal 20_1 and a subscriber of the network 22 is effected via the station 18. In other words, when a subscriber of the network 22 calls the subscriber 20_1 , the signal is transmitted to the station 18 which transmits it to the terminal 20 via the satellite 14.

Each terminal is simultaneously a transmitter and a receiver and the connection station 18 also transmits and receives simultaneously. Thus, in Figure 1, the transmitter 10 is either in a terminal or in the connection station 18 and the receiver 12 is likewise in the station 18 or in a terminal 20_i .

A signal transmitted by the transmitter 10 propagates in space, which constitutes a channel 28 (Figure 10) which attenuates the signal and introduces noise.

In the conventional way, the receiver 12 includes a receiver unit 30, a unit 32 for estimating the power E_b of the signal and a unit 34 for estimating the power N_0 of the noise.

In the invention, the signal estimator unit 32 is followed by a signal filter unit 36 downstream of a divider 40. In other words, the output of the unit 36 is connected to the numerator input 42 of the divider 40.

The noise power N_0 estimator unit 34 is followed by a filter 44 downstream of the divider 40 whose output is connected to the denominator input 46 of the divider 40.

The divider 40 supplies an estimate of the signal-to-noise ratio to a decision unit 50 which has an input 52 to which a reference signal y_{ref} is applied. The signal supplied by the divider 40 and the reference signal applied to the input 52 are compared to generate a set point δP_e for adjusting the power of the transmitter 10.

As an alternative to this (not shown), the decision unit is in the transmitter and the receiver transmits the

signal-to-noise ratio (the output from the divider 40) to a control input of the transmitter.

Consider first the situation in which the transmitter 10 is in the connection station 18 and the receiver 12 is in a terminal 20_i. In this situation, measuring the signal-to-noise ratio is facilitated by the transmission of a periodic reference signal from the station 18 to the terminals 20_i. This is a synchronization signal of particular level and known period. Accordingly, in this case, the receiver 12 can use the synchronization signal to measure the signal-to-noise ratio, instead of using the wanted signals, which are by nature sporadic.

In this case, the filter 36 for the wanted signal can be a simple averaging circuit performing the following operation:

$$\hat{x}_i = \frac{1}{L} \sum_{j=0}^{L-1} \tilde{x}_{i-j}$$

where \tilde{x}_i represents the instantaneous estimate of E_b at time i , \hat{x}_i represents the smoothed estimate of E_b at time i and L is the integration length.

In this example, the filter 44 samples the noise signal N_0 with a period of 1.5 ms over a time period of a few seconds and takes the maximum value observed during that time period.

As an alternative to this, over a particular time period T , chosen to be sufficiently long to collect a sufficient number of measured values but sufficiently short to guarantee stationary noise behavior, the parameters associated with the distribution (histogram) of the noise samples are calculated to deduce therefrom a noise level $\mu_{N0} + \Delta_{N0}$ such that the probability that the instantaneous noise value exceeds that level is less than ε , in other words:

$$P(\forall i \in [0, T], \tilde{N}_0(i) > \mu_{N0} + \Delta_{N0}) < \varepsilon$$

In the above equation, $\tilde{N}_0(i)$ represents the value of

a noise sample of the distribution at time t_i , T the observation period and μ_{N0} the average value of the noise signal.

The above equation is represented by the Figure 3 diagram, in which the instantaneous noise levels \tilde{N}_0 are plotted on the abscissa axis and the probability $p(\tilde{N}_0)$ of appearance of those levels on the ordinate axis.

The value adopted $\mu_{N0} + \Delta_{N0}$ can be calculated using moments of the distribution, in particular the average μ and the variance σ^2 . In this latter case, the smoothed value is $\mu + n\sigma$, for example, where σ is a standard deviation and n is an integer chosen according to the value of ε adopted.

Then consider the situation in which the transmitter 10 is in a terminal and the receiver is in the connection station 18. In this case, the terminal does not send any periodic reference signal to the connection station, only sporadic data signals in the form of cells or packets, and the signal power E_b is estimated in the receiver for each packet or cell. The noise can be estimated with a regular period, as in the previous situation.

Accordingly, in this case, the filtering 44 of the noise is effected in the same manner as under the previous hypothesis. On the other hand, it is preferable to allow for the sporadic nature of the transmission in smoothing or filtering the signal (36). A first order auto-regressive filter is used to perform the following operation, for example:

$$\hat{x}_i = (1-a)\tilde{x}_i + a\hat{x}_{i-1}$$

where \tilde{x}_i represents the instantaneous estimate of E_b at time i , \hat{x}_i represents the smoothed estimate of E_b at time i and a is an integration coefficient.

A filter of the above kind is better suited to the sporadic nature than an average because, as shown by the preceding equation, it gives more weight to more recent data than to less recent data.

The method according to the invention provides an

estimate of the signal-to-noise ratio of the received signal enabling a set point to be applied to the transmitter. It is therefore possible to minimize the power transmitted whilst conforming to a bit error rate
5 that does not exceed a prescribed threshold.

The above statistical processing of the noise is particularly beneficial and efficient in a situation in which the telecommunications system shown in Figure 2 has two adjoining areas 16 using the same carrier frequency.
10 In this case there is a risk of jamming in neighboring or non-neighboring parts of the two areas and therefore of unpredictable noise in those parts.